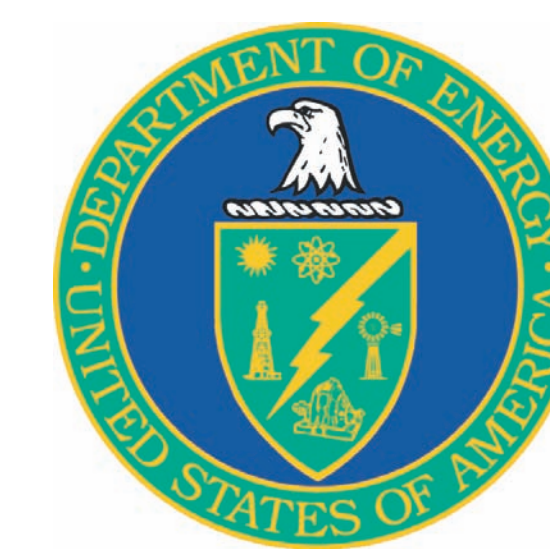


Well Blowout Rates in California Oil and Gas District 4: Implications for Carbon Storage Field Development and Operation

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OBJECTIVES

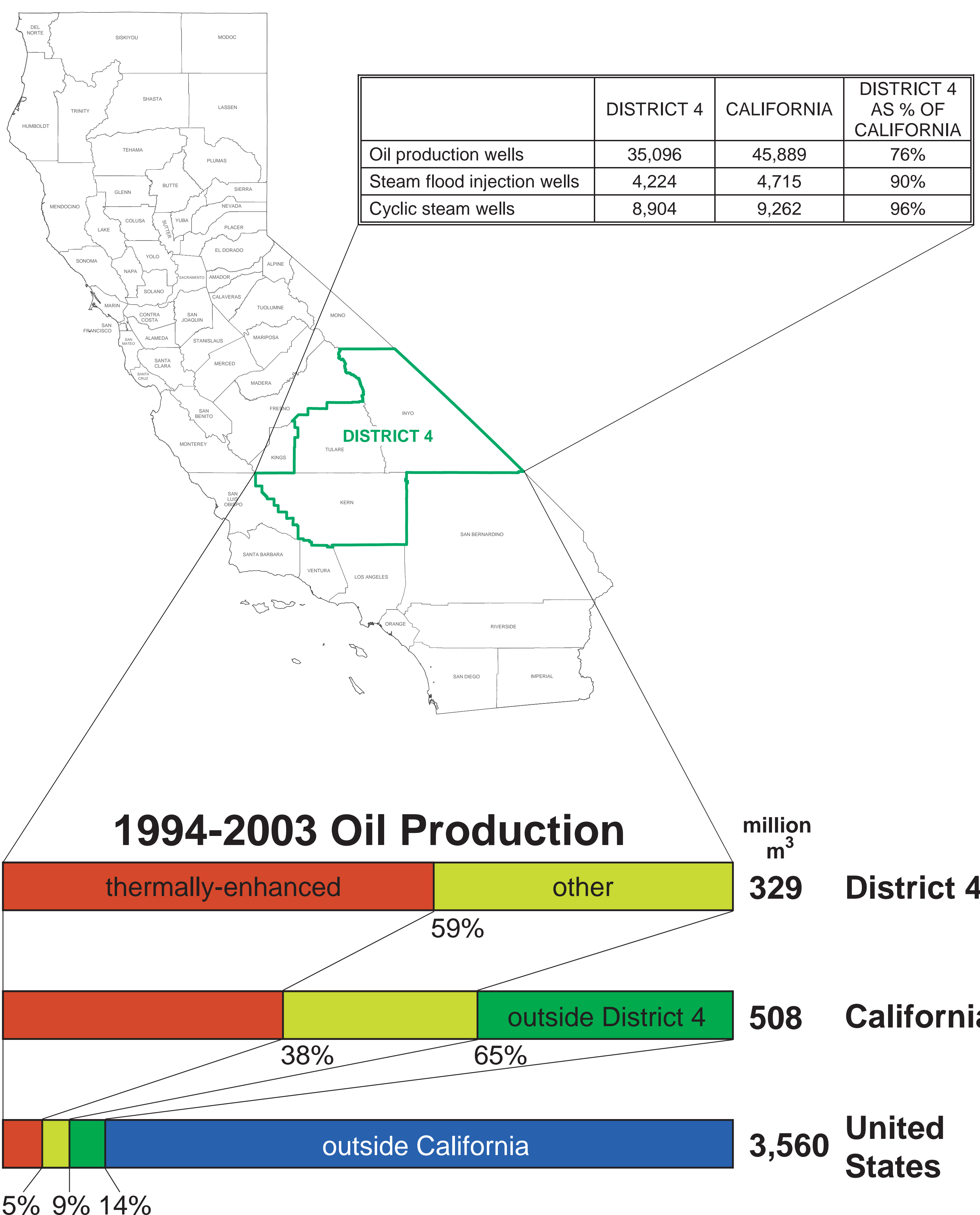
Leakage from abandoned and active wells is considered to pose perhaps the largest source of risk for geological storage of CO₂ (Gasda et al., 2004; Benson and Cook et al., 2005). The IPCC Special Report on Carbon Dioxide Capture and Storage concluded the local risks of geological CO₂ storage would be similar to existing activities (Benson and Cook et al., 2005).

Leakage from a well is called a well blowout. Such leakage to the surface is called a surface blowout (Hauser and Guerard, 1993). The purpose of this study was to determine the frequency of surface blowouts in terrestrial oil fields with enhanced-recovery injection, and discuss the implications of these rates for carbon storage fields.

BACKGROUND AND DATA

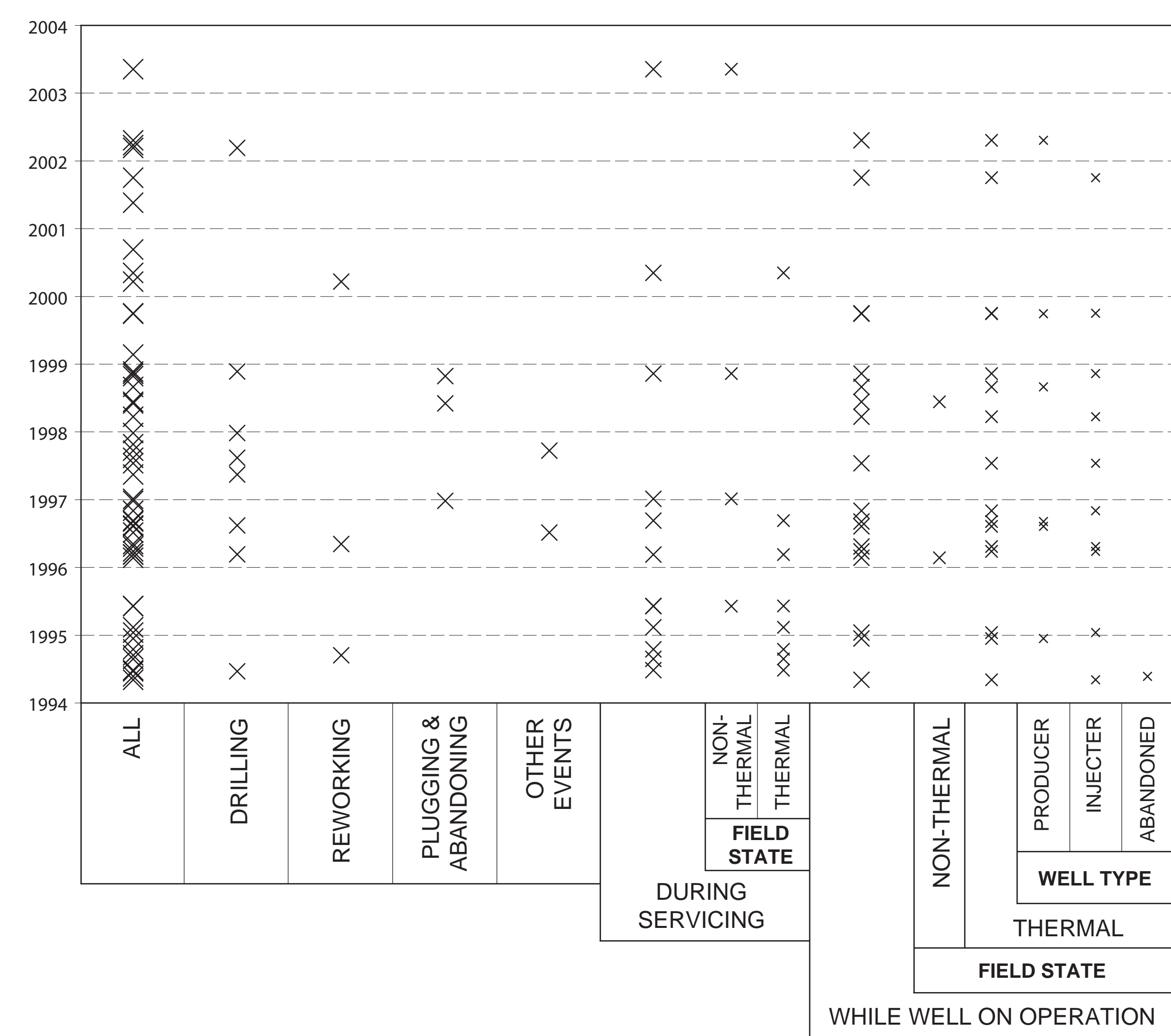
The California Division of Oil, Gas and Geothermal Resources (DOGGR) provided surface blowout data for California Oil and Gas District 4. District 4 is a prolific producer of oil and about three fifths of this production is via thermally-enhanced recovery by steam injection, as shown below.

The blowout data provided by DOGGR included the date, location and cause of the blowout, and the activity taking place at the time of the blowout. We analyzed the data from 1994 to 2003.



ANALYSIS

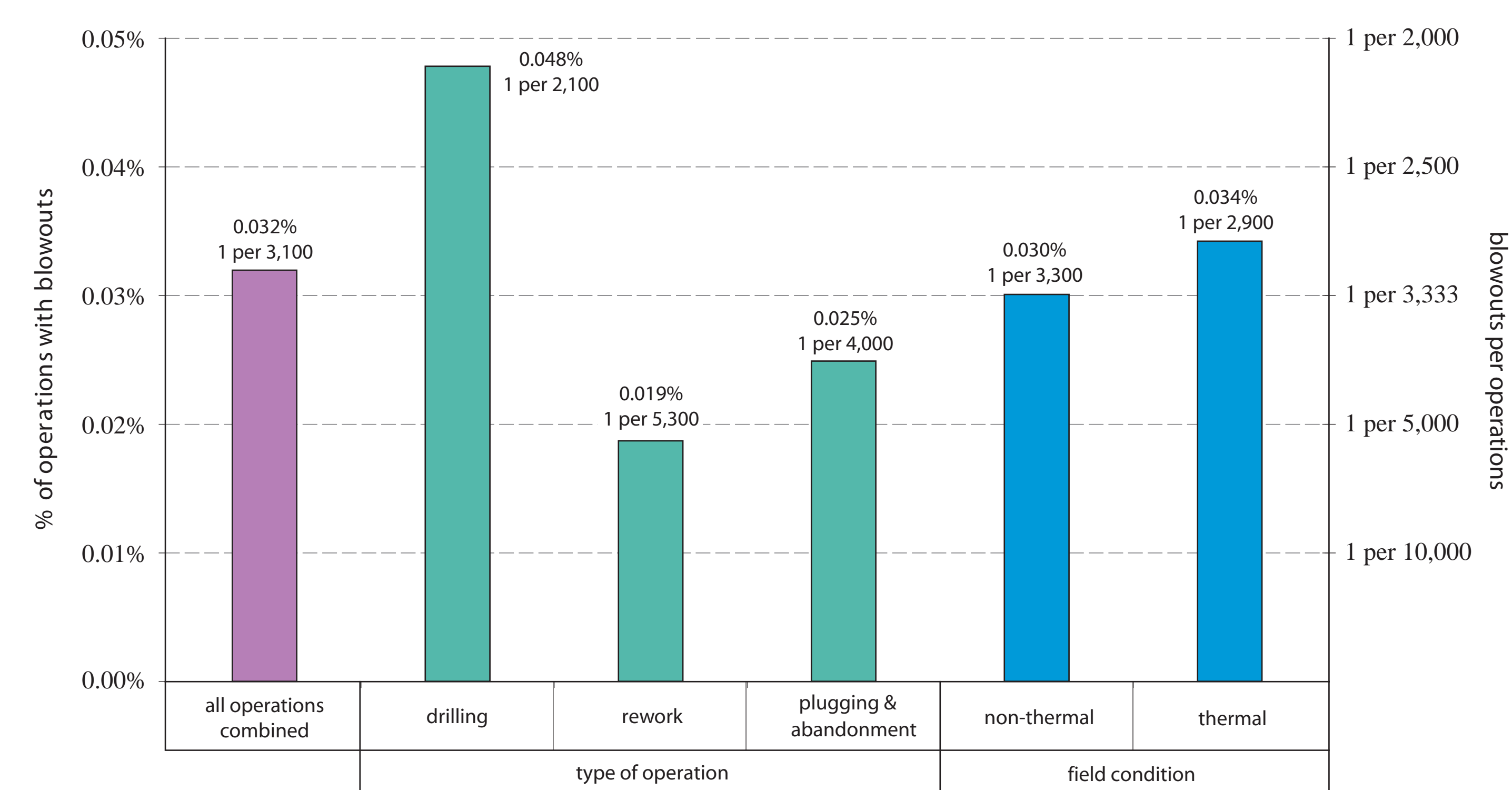
Surface blowouts were classified according to the type of operation at the time of the blowout, occurrence in a field with or without thermally-enhanced recovery, and the type of well. Below is a timeline of blowouts by selected classes. Note some classes are hierarchical, such as blowouts from injection wells in thermal fields while the well was on operation.



Depending on the class, blowout rates are either blowouts divided by well construction operations or blowouts divided by annual average well total and total fluid-volume transferred during the study period. These values are available in DOGGR's "Annual Report of the Oil and Gas Supervisor."

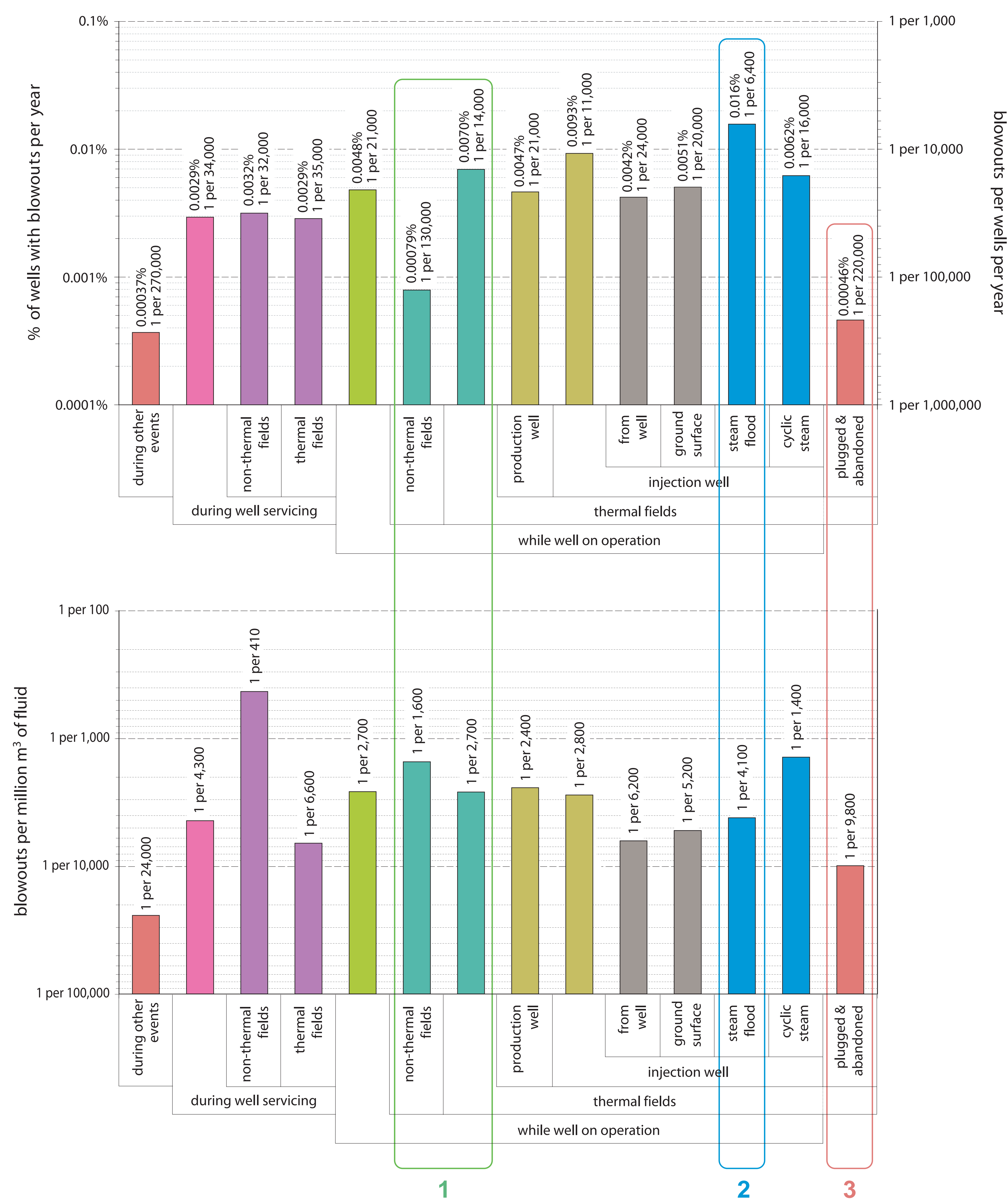
These reports list the liquid equivalent of steam injected. These volumes were converted to two-phase (vapor and liquid) volumes assuming a 70% steam mass fraction at 3 MPa at injector well heads, a 35% steam mass fraction at 5 MPa in the reservoir, and a 10% steam mass fraction at 1 MPa at production well heads. The steam volume was many times greater than the volume of all other fluids transferred (water, oil, gas, air) combined.

BLOWOUT RATES DURING WELL CONSTRUCTION & ABANDONMENT



- The well construction blowout rates do not differ significantly between fields with and without thermally-enhanced recovery.
- The decline from drilling to abandonment blowout rates in carbon storage fields will likely be reversed from that in oil fields due to the upward trend in pressure and dissolved gas content in carbon storage fields as compared to the general downward trend in oil fields.
- Even so, the abandonment blowout rate in carbon storage will likely be less than the drilling blowout rate in oil fields due to better knowledge of reservoir conditions at the time of abandonment as compared to drilling.

BLOWOUT RATES DURING WELL OPERATION



- Operational well blowout rates per well per year are significantly higher in fields with steam injection than those without, but rates per fluid-volume transferred are somewhat lower.
- The blowout rate from steam flood injection wells is the highest measured for any group of wells on operation on a per well per year basis, but the lowest on a fluid-volume transferred basis.
- The blowout rate from abandoned wells in steam-injection areas is exceedingly low at 1 per 220,000 wells per year. There was only one such blowout in the district in the 10-year study period. This blowout was from a previously abandoned well and occurred the day after reservoir repressuring.

There were no blowouts from previously unknown or poorly located wells. This is particularly noteworthy given over a century of exploration and production in the district.

CONCLUSIONS

- Surface blowouts are relatively infrequent events, occurring in 0.03% of all well construction operations, 0.005% of operational wells per year, and 0.0005% of abandoned wells per year.
- Steam flood injection wells had the highest surface blowout rate among operational wells on a per well basis (0.016% of wells per year or 1 per 6,400 wells per year), but the lowest rate measured on a per fluid-volume basis (1 per 4,100 m³ fluid injected).
- Only one surface blowout occurred during the ten-year study period from the over 20,000 abandoned wells in areas with steam injection.
- No surface blowouts occurred from previously unknown or poorly located wells, despite over a century of exploration and production in the district.
- The blowout rate for CO₂-injection wells is likely lower than for steam-flood injectors because well degradation from the corrosive effects and thermal stresses of steam is likely greater than for dry CO₂. Conversely, the average operating pressure of 3 to 5 MPa for steam flood injectors in District 4 is lower than the minimum 8 to 10 MPa operating pressure envisioned for cost-effective CO₂ injection, suggesting the blowouts rates for CO₂-injection could be greater than those presented here for steam flood injectors. Given these contrasting factors, it seems unlikely the blowout rate for CO₂ injectors will be less than for District 4 steam injectors by more than a few factors, and it could well be the same.
- Blowouts during drilling to develop carbon storage fields will likely be closer to the District 4 rate for plugging and abandoning (1 per 4,000 operations) than for drilling (1 per 2,100 operations) owing to lower relative pressures and dissolved gases initially in carbon storage fields as compared to oil fields.
- Conversely, blowouts during plugging and abandoning in carbon storage fields will likely be higher than in District 4, but will probably not reach the District 4 drilling blowout rate due to greater knowledge about reservoir conditions at the time of abandoning versus drilling.
- Similar studies in diverse geological settings and under a number of different oil field operations, particularly CO₂-EOR, would expand the applicability of existing blowout information for quantitatively assessing risks in CO₂-storage projects.

REFERENCES

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